SENIOR THESIS

DEPOSITIONAL OCCURRENCE OF A *XENOCRINUS PENICILLUS* S.A. MILLER (CRINOIDEA) BED IN THE UPPER ORDOVICIAN OF SOUTHWESTERN OHIO

BY

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1987

This report is submitted as partial fulfillment of the requirements for the Bachelor of Science degree in Geology and Mineralogy at The Ohio State University, Winter Quarter, 1987.

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ACKNOWLEDGEMENTS

I wish to thank Dr. William Ausich for his help in the field, laboratory and with the manuscript work. I also wish to thank Kenneth Coates and Greg Bakeman for their donations and use of fossil specimens. Finally, I wish to thank Jane Prigosin for her help with the preparation of figures and Steve Riddle for his help with the printing of the photographic plates.

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

A bed of excellently preserved Xenocrinus penicillus S. A. Miller (Crinoidea) from the Upper Ordovician Bull Fork Formation is interpreted to be the result of storm deposition. A single bed contained 44 X. penicillus crowns, and some specimens had lengths of stem attached. This materal is from a 10 m section of Upper Ordovician strata in Warren County, Ohio. The entire sequence, as well as the crinoid bed, is interpreted to be storm dominated based upon the following criteria: beds vary in thickness and pinch-out, generally fine upwards, have sharp erosional bases and gradational upper contacts; ripple cross and horizontal laminations are present, and cement filled voids are common.

INTRODUCTION

The purpose of this report is to present the results of a study of the depositional setting of a *Xenocrinus penicillus* S. A. Miller bed in the Upper Ordovician of Ohio. *Xenocrinus* is a monobathrid camerate crinoid. This study will lead to a better understanding of the paleoecology of fossiliferous deposits in this region.

Location of Study

This study was conducted in Warren County, Ohio which is about 64 miles or 103 kilometers south of Columbus, Ohio. The exposure is a stream cut along Flat Fork tributary, which is west of Oregonia Road and south of State Route 73 (see Fig. 1). It is located near 84 degrees 02′ 30′′ W longitude and 39 degrees 30′ N latitude as in the Oregonia 7.5′ quadrangle. Flat Fork is a small tributary of Caesar Creek Reservoir, which is nearby.

Purpose and Objectives

The purpose of this study is to determine the depositional history and the paleoecologic occurrence of a *Xenocrinus penicillus* bed. The sedimentology of the beds is examined. Paleontology will involve crinoid description, preservation and consideration of the remainder of the fauna. Stratigraphic and lithologic observations and interpretations were made both in the

1 Caesars Creek Lake
2 Caesars Creek
3 Miami River
4 Oregonia Road
5 Harveysburg
6 Study Site

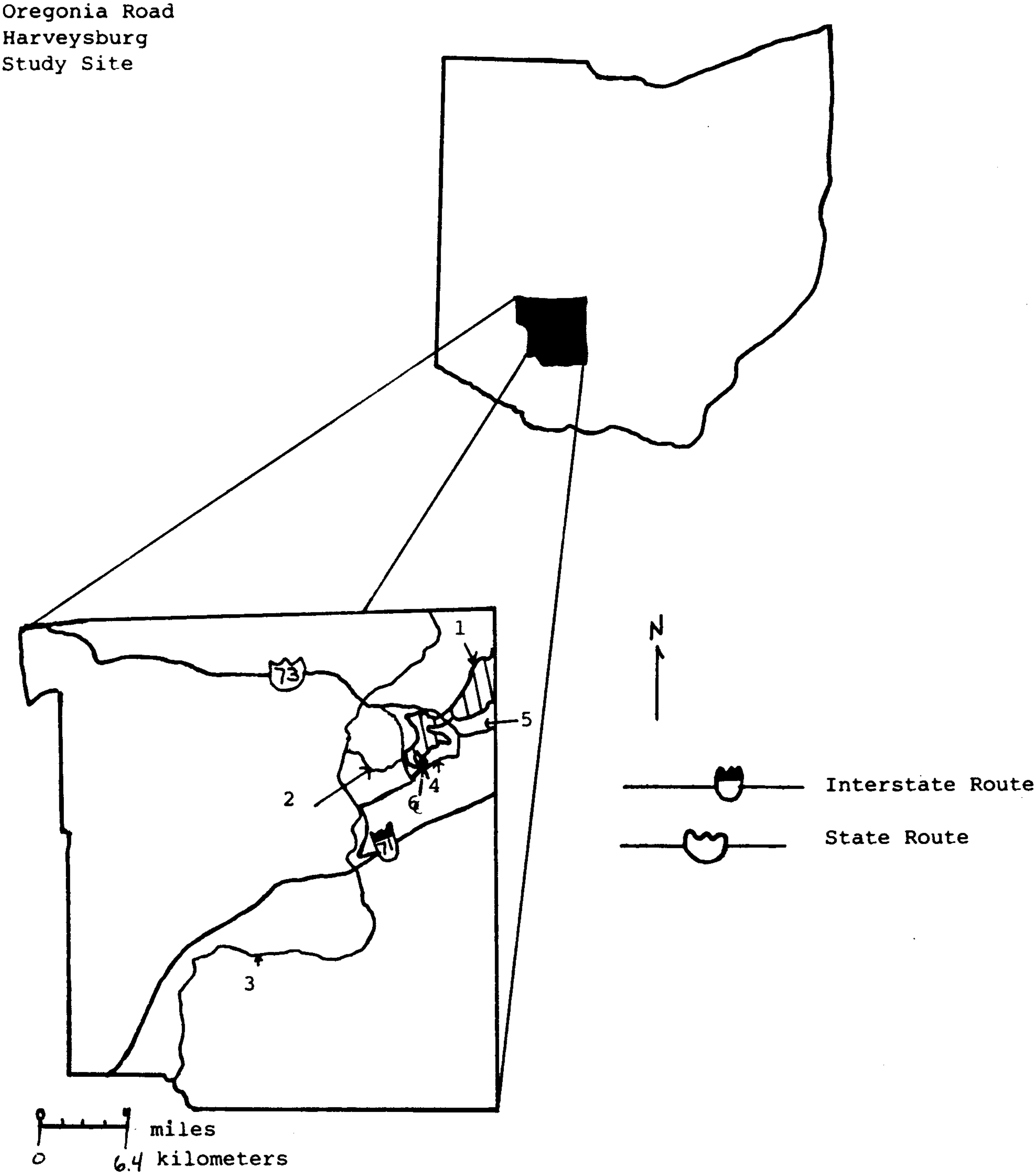


Figure 1
LOCALITY MAP OF WARREN COUNTY, OHIO

field and in the laboratory. The methods used are described in the following section.

Field Methods

Field measurements and observations were made at the site. A generalized stratigraphic column was made, and samples of rocks and fossils were collected, for further study. Nearby locations were studied for comparison and fossil collection.

Equipment used included a Brunton compass, tape measure (metal), Jacob staff, 30 ft. Aluminum ladder, rock hammer, cold chisel, hand lens(10x), cloth sample bags, hydrochloric acid (3 molar), 35mm camera and film, field notebook and pencils. Samples were removed from the measured section for laboratory study. The fossil samples were collected by Kenneth Coates, Greg Bakeman, Dr. William Ausich and the author. Samples were labelled and bagged for transportation to the laboratory.

Laboratory Methods

Lithologic samples were cut on a circular saw (water) and on an oil saw. Blanks for thin sections were cut. Next, the blanks were polished on laps with 200 and 400 grit. The blanks were sent to the thin section lab for preparation. The thin sections were studied under a petrographic microscope.

Fossils were cleaned with a hard bristle brush and water. They were then boiled in "Quaternary O" and brushed again, and needles were used to remove excess rock from the specimens. Fossils were studied under a stereomicroscope. A drawing column was used to sketch specimens. The specimens were coated with ammonium chloride before photographs were taken with a 120mm Bronica camera with a 75mm lens. Kodak Panatomic X 32 ASA film was used. The negatives were used to make enlarged prints of the crinoids.

LITHOLOGY

Field Descriptions

Most crinoids were found in a debris pile at the base of a 10 meter(m) vertical exposure. The exposure contained 50% limestone and 50% shale with the upper 0.5 m being soil (Fig. 2, Fig. 3). The beds were mostly horizontal with slightly varying dips. The general character of the limestone beds, which pinched out within a horizontal distance of 1.0 m, was lenticular to irregular. The limestone beds mostly fine upwards and were gradational with overlying shales. The bases of the limestones were sharp with some irregularities commonly containing evidence of scouring (Fig. 4). Cross-bedding was present in a coarser grained limestone bed (Fig. 5). Sinuous megaripples were present a few meters upstream from the site (Fig. 6). The strike of these ripples was N 26 E, suggesting a northwesterly flow.

A detailed measured section was described for the lower 1.0 m of the 9.4 m cliff (Fig. 7, Fig. 3). The crinoids seem to have fallen from the 7.5 m level of the cliff (Fig. 8). The section described begins at the exposed base of the cliff just above the creek bed. The classification followed is that of Folk (1959) and Dunham (1962) (Fig. 9 & 10). The rock units, descriptions and types are listed in the table below:

Figure 2
VERTICAL EXPOSURE
Hammer is 31 cm in length.

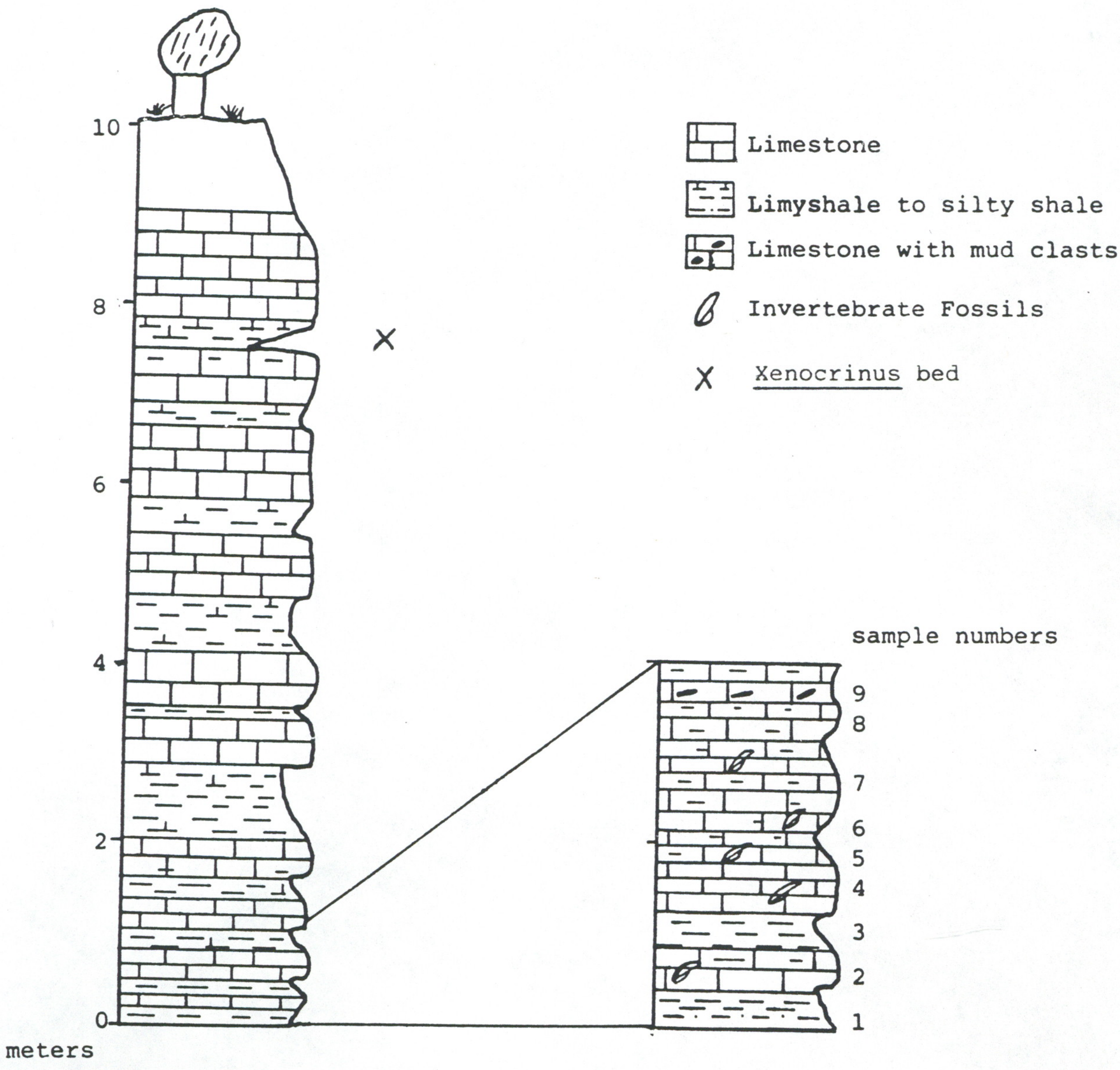


Figure 3
STRATIGRAPHIC COLUMN, GENERAL AND SPECIFIC

Figure 4

BASAL CONTACT LIMESTONE AND SHALE

Figure 5
CROSS-BEDDING

Figure 6

MEGARIPPLES

Figure 7

MEASURED SECTION

Figure 8
SUGGESTED CRINOID LOCATION

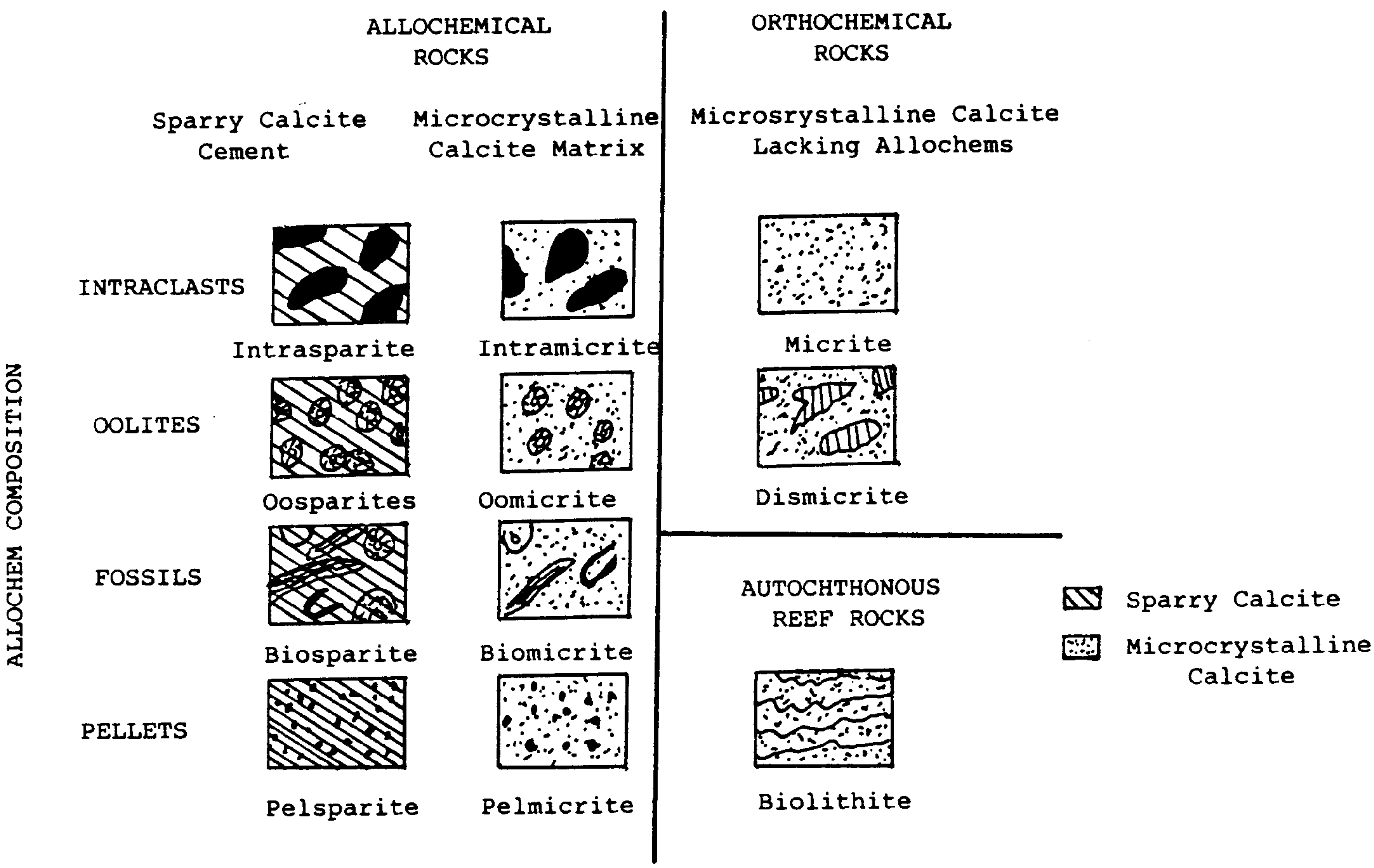


Figure 9

CARBONATE ROCK CLASSIFICATION (MODIFIED FROM SCHOLLE, 1978; FOLK, 1959)

<table>
<tr><td colspan="5">DEPOSITIONAL TEXTURE RECOGNIZABLE</td><td rowspan="5">DEPOSITIONAL TEXTURE NOT RECOGNIZABLE</td></tr>
<tr><td colspan="4">Original Components Not Bound Together During Deposition</td><td rowspan="4">Original components were bound together during deposition</td></tr>
<tr><td colspan="3">Contains mud
(particles of clay and fine silt size)</td><td rowspan="3">Lacks mud and is grain supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain supported</td></tr>
<tr><td>Less than 10 percent grains</td><td>More than 10 percent grains</td></tr>
<tr><td>MUDSTONE</td><td>WACKESTONE</td><td>PACKSTONE</td><td>GRAINSTONE</td><td>BOUNDSTONE</td><td>CRYSTALLINE CARBONATE</td></tr>
</table>

Figure 10
CARBONATE ROCK CLASSIFICATION (MODIFIED FROM SCHOLLE, 1978; DUNHAM, 1962)

Table 1 Field Descriptions

Rock Unit*	Description	Folk	Dunham
1	grey, argillaceous, silty, nonfossiliferous, fissile, limestone	Micrite	Mudstone to Wackestone
2	grey, limestone, brachiopods, secondary calcite crystals	Biomicrite Biosparite	Packstone Grainstone
3	limy, shale	Micrite	Mudstone
4 (upper) 4 (basal)	limestone, brachiopods, secondary calcite, laminations	Biomicrite Biosparite	Packstone Grainstone
5	argillaceous, fissile, basal brachiopods, limestone	Biomicrite	Packstone
6	limestone, basal brachiopods, secondary pyrite & calcite	Biosparite	Grainstone
7	argillaceous, fissile, limestone, brachiopods	Biomicrite	Wackestone
8	limestone, clay clasts, secondary calcite, fossiliferous	Biomicrite	Wackestone

9	argillaceous limestone, basal mud clasts, fossiliferous	Biomicrite	Packstone
10	blue-grey limestone, fossiliferous-crinoids & bryozoans, silt, mud clasts, tan surfaces, voids	Biomicrite	Wackestone

* Refer to Figure 3 for stratigraphic position of rock units

Laboratory Study

The thin section descriptions are based on information from Scoffin (1987) and Scholle (1978). A brief summary will be given for each thin section. The corresponding number is given for location in the measured section (see Fig. 3, Table 1).

2

Coarse-grained fossiliferous limestone containing 40% fossils- brachiopods 2 mm to 10 mm with foliated calcite in parallel leaves, bryozoans 1 mm to 4 mm with calcite inclusions, ostracodes 0.1 mm to 0.4 mm with unidirectional extinction, trilobite spines 0.5 mm, echinoderm pieces 0.1 mm to 0.3 mm in diameter; 7% opaques- organics and pyrite; 53% matrix- with sparite, recrystallized rhombs 0.1 mm likely calcite, intraparticle pores 0.01 mm to 1 mm, some clay clasts.

5

Coarse-grained fossiliferous limestone containing 45% fossils- brachiopods 2 mm to 5.5 mm with wavy parallel laminated shell structure, ostracodes 0.1 mm to 0.4 mm with undulatory extinction, echinoderm plates 0.15 mm with clay clogged pores and basal view of a 0.7 mm crinoid, bryozoans 0.1 mm to 0.3 mm diameter; 5% opaques- round with fossils as inclusions; 55% matrix- mostly micrite with some recrystallized calcite rhombs 0.1 mm.

9

Fine grained limestone, fining upwards containing 70% fossils- mostly broken, bryozoans 0.1 mm to 0.5 mm in diameter, ostracodes 0.2 mm to 0.4 mm, echinoderm plates < 0.01 mm to 0.3 mm columnals, trilobite spines 0.01 mm to 0.1 mm; 3% opaques- pyrite cubes 0.2 mm, red iron stains, clay particles; 27% matrix- mostly micrite with some calcite crystals.

4 (upper)

Fossiliferous limestone containing 37% fossils- brachiopods of foliated calcite 2 mm to 5.5 mm, bryozoans 0.5 mm to 0.7 mm in diameter, echinoderm plates 0.1 mm hexagonal, ostracodes 0.2 mm to 0.5 mm, trilobite fragments 0.6 mm, mollusc mostly 2 mm, corals mostly 0.5 mm; 3% opaques- irregular shape with some brown organics 0.1 mm; 60% matrix- mostly micrite, 0.2 mm rhombs and irregular pieces, central part recrystallized, zircon crystal 0.01 mm.

4 (basal)

Fossiliferous, thinly bedded limestone with a subparallel fabric containing 27% fossils- brachiopods broken pieces 1 mm to 2 mm of foliated calcite, a nautiloid 0.6 mm of crystalline calcite, ostracodes mostly 0.2 mm, bryozoans mostly 0.3 mm, 3% opaques- 0.1 mm dark bands, iron stains; 70% matrix- mostly sparite at base and top, micrite in the middle with smaller sized fossils.

X

Fossiliferous limestone containing 20% fossils- bryozoans mostly 0.5 mm diameter some 1.2 mm length, echinoderm plates of calcite mostly 0.2 mm hexagonal, 1.2 mm longitudinal section of column; 1% opaques- irregular shapes 0.01 mm to 0.3 mm; 79% matrix- vugs filled with biomicrite and red iron stains, some clays, secondary calcite rhombs mostly 0.1 mm.

The above descriptions will be used to suggest the depositional environments.

Paleoenvironment

The carbonate rocks from the Upper Ordovician represent a complex environment of deposition. During the time interval of 500 to 430 million years ago, the geographical location of Ohio was covered by a shallow epeiric sea with bottom slope of less than .005 degrees (Scoffin, 1987, p.12; Davis, 1981). During the Middle Ordovician, Ohio was located near 15 degrees S latitude (Bambach, Scotese and Ziegler, 1980, p.30).

The limestones and shales previously described are of marine origin based on the fossils content. Although the beds are mostly horizontal, the varying dips could be a reflection of local differences in topography in the Upper Ordovician sea floor. The lenticular, irregular beds seem to represent a dynamic depositional environment. The gradational tops suggest a decreasing energy level during deposition of single beds, whereas scour features at the base of the beds indicate erosion. A rapid energy increase would account for the sharp basal limestone contacts.

Cross-bedding in limestones represents movement of sediment by bottom currents. The megaripples must have required a high energy level for formation. However, the argillaceous limestone and shale units were deposited in quiet waters.

These deposits contain secondary minerals such as recrystallized calcite and pyrite. Weathering is evident at this exposure because of the iron stains. The pore spaces found in a few samples could represent dissolution of allochems.

Storm-dominated depositional environments have been suggested for similar deposits from the Middle and Upper Ordovician of southwestern Virginia. Characteristics of storm deposits according to Kreisa (1981, p.823-825) include the following: beds varying in thickness laterally which pinch-out, generally fining upwards sequences, sharp erosional basal contacts, diffuse burrowed upper contacts, wave ripple cross laminations, horizontal laminations, cement filled voids, packstones with mud grading into shales. Similar deposits from the Cincinnatian Series contain evidence of cyclic bedding (Meyer and Tobin, 1981, p.44-45). Interpretations include shoaling upwards sequence, alternating storm and non-storm events, patchy faunal distributions and other physical limits as well as erosional processes.

STRATIGRAPHY

History of nomenclature

The crinoids were preserved on the basal and upper surfaces of a limestone in an exposure containing shale and limestone beds from the Upper Ordovician. Specifically, the rocks in this exposure are from the Richmondian Stage of the Cincinnatian Series. The formation name in question is difficult to determine since the rocks change types rapidly.

The stratigraphic nomenclature for rocks of this age is a constantly improving classification. Daniel Drake was the first to study the Upper Ordovician limestones and shales of the Cincinnati Arch region in 1825 (Schumacher, 1984, p.8). Many advances have been made from that time to the present and are summarized in Fig. 11. According to Meyer and Tobin (1981, p.31), the concepts of Cincinnatian geology have not yet answered the questions of paleoecology, modes of sedimentation or depositional environments.

Many schemes have been used in the past to classify the stratigraphy; a list has been compiled by Schumacher (1984, p.13) and appears in Fig. 12. The units included are located in Ohio, Indiana and Kentucky with nomenclature varying from state to state. The specific unit in question will be generally placed in a formation based on certain indices.

Author and Publication Date	Summary of Article
Weiss and Sweet (1966)	Defined the Kope Formation of Ohio and Kentucky
Weir, Greene and Simmons (1965)	Defined the Calloway Creek Limestone, the Ashlock Formation and the Drakes Formation for southcentral Kentucky
Brown and Lineback (1966)	Defined the Dillsboro Formation, the Saluda Formation and the Whitewater Formation of southeastern Indiana. Also used the term "Kope Formation"
Peck (1966)	Defined the Grant Lake Limestone and the Bull Fork Formation for the Maysville, Kentucky, area. Also used the terms "Kope", "Fairview" and "Drakes" formations
Ford (1965, 1967)	Defined the Fairview Formation, the Miamitown Shale, and the Bellevue Limestone for the Cincinnati area. Also used the term "Kope Formation"
Hatfield (1968)	Defined the Tanner's Creek and Whitewater formations, and redefined the Saluda Formation for southeastern Indiana and northcentral Kentucky
Lee (1974)	Used the terms "Kope", "Fairview", "Grant Lake", and "Bull Fork" for the area between Dayton, Ohio, and Maysville, Kentucky. Proposed the names Waynesville Formation and Whitewater Formation be used for two intertonguing units in the Bull Fork
Martin (1975)	Used the following lithologic units: Kope, Fairview, Saluda, Whitewater, and Drakes. Also used the following biostratigraphic units: McMillan, Arnheim, Waynesville, and Liberty

Figure 11

SUMMARY OF LITHOSTRATIGRAPHIC UNITS
(MODIFIED FROM MEYER AND TOBIN, 1981)

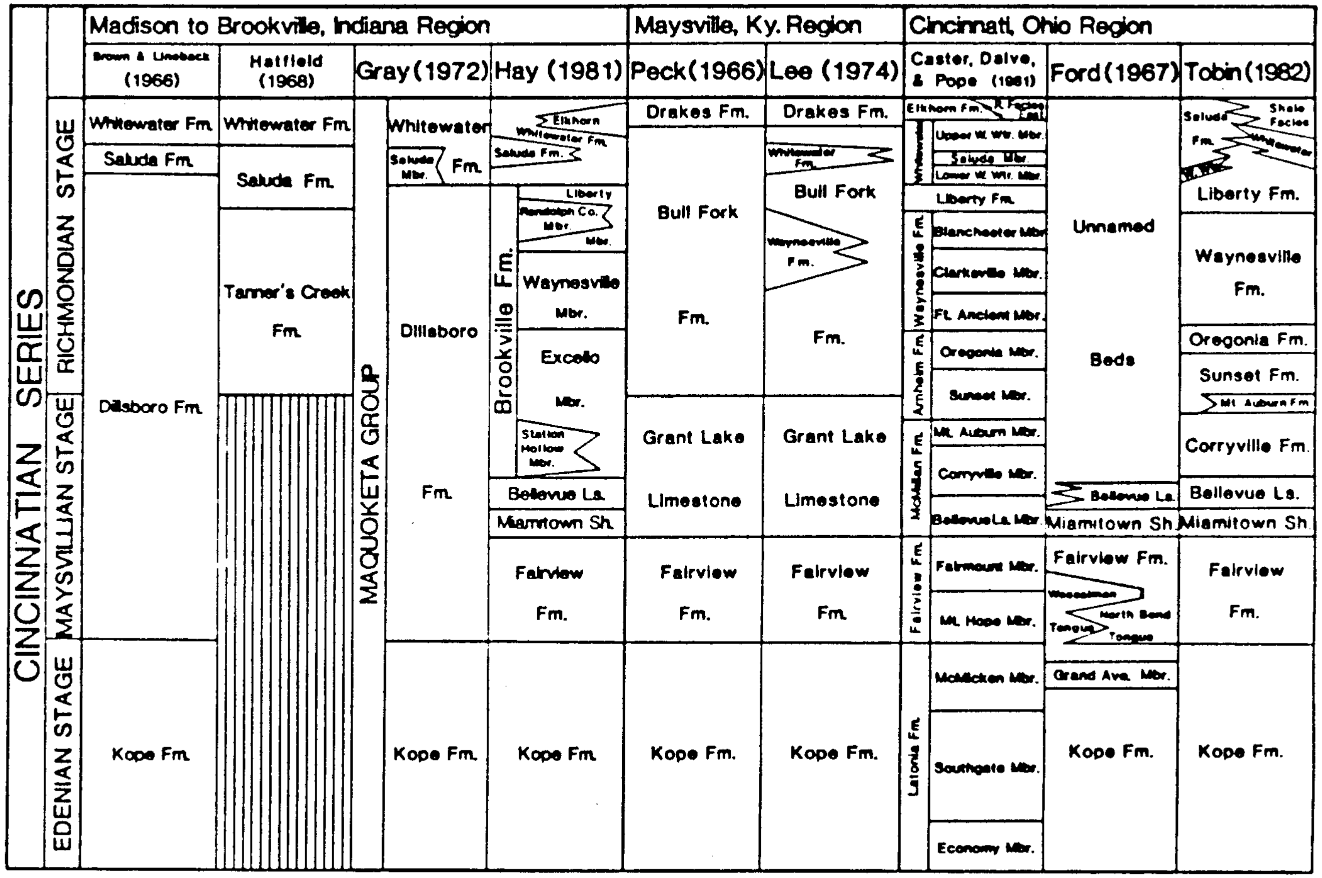


Figure 12
CINCINNATIAN STRATIGRAPHIC NOMENCLATURE AFTER 1960
(MODIFIED FROM SCHUMACHER, 1984)

Stratigraphic nomenclature is based on lithology and faunal units or both. Lithostratigraphy deals with the organization of strata based on lithologic character (Hedberg, 1976, p.8). Clastic ratios and bedding index logs have been used for correlation by Sweet and Weiss (1969, p.4). Other units are determined by faunal ranges. Biostratigraphic units were used to combine the lithologic and faunal units by Caster, Dalve and Pope (1955).

Suggested Formation

Formations in this geographic location include units of the Cincinnatian. The study section is within the Bull Fork Formation of Peck (1966). The faunal characteristics and the clastic ratio of 50% limestone and 50% shale of the study section suggest that these beds may be equivalent to the Liberty Formation interval of Caster, Dalve and Pope (1955). These rocks are composed of packstones, grainstones and shales. This represents a transition from low to high energy.

PALEONTOLOGY

General

In the vicinity of Caesar Creek Reservoir many species of fossil invertebrates are known, including 2 echinoderm classes represented by 8 genera (Ausich and Schumacher, 1980). The echinoderms discussed in this report were not found in situ but in float. Most of the echinoderm specimens studied are deposited in the Orton Musuem at The Ohio State University (OSU), while others belong to several amateur paleontologists.

Non-echinoderm fauna

The fossil preservation of this site ranges from good to excellent. Many phyla are represented. A few of the fossils at this locality and nearby localities were identified. Benthic organisms, including trilobites and other arthropods, were observed. Nektonic animals, cephalopods, were also represented. The following table is a list of fauna collected:

Table 2 Fossils

Arthropoda

Flexicalymene meeki

Isotelus sp.

Ostracoda

In thin section

Anellida

Scolecodonts

Brachiopoda

Herbertella sp.

Lepidocyclus capax

Laptaena sp.

Onniella meeki

Platystrophia sp.(?)

Rafinesquina sp.

Strophomena sp.(?)

Bryozoa

Hallopora sp.

Many others

Corals

Grewingkia canadaensis

Tabulata

Crinoidea

Cincinnaticrinus sp.

Xenocrinus penicillus

Mollusca

Cephalopoda

Nautiloidea

Gastropoda

Sinuites sp.(?)

Trace fossils

Cruziana

The types of preservation included replacement, molds, casts and trace fossils. This locality contains a good marine faunal record of the Upper Ordovician.

Systematic Paleontology

Class CRINOIDEA Miller, 1821

Subclass CAMERATA

Wachsmuth and Springer, 1885

Order MONOBATHRIDA

Moore and Laudon, 1943

Suborder COMPSOCRININA Ubaghs, 1953

Superfamily XENOCRINACEA S.A. Miller, 1890

Family XENOCRINIDAE S.A. Miller, 1889

Diagnosis.- Camerate crinoids lacking infrabasals, with four basals, numerous connecting interradials, free arms a few per ray and hexagonal basal circlet.

Description.- Crinoids with a rigid cup and pinnulate arms. The Xenocrinus have a median ray and anal ridges conspicuous with sutures between adjacent radials covered by supplementary plates. There are two fixed secundibrachs, or 3 to 4 to each half ray. The interbrachial areas are depressed and composed of many small irregular plates. The CD interray is not visible in any of the specimens studied. Two free arms per ray, each unbranched, uniserial and composed of cuneate brachials are present. The stem is quadrangular in cross section with a pentagonal axial canal.

Discussion.- This definition of the Xenocrinidae follows that of S.A. Miller (1890, p.318) including Xenocrinus. Other information is from Ramsbottom (1961). The age of this family is Upper Ordovician (Richmond-Ashgillian).

Genus XENOCRINUS S.A. Miller 1881

(non Xenocrinus Jahn, 1893 = Ctenocrinus Bronn)

Diagnosis.- This primitive monocyclic camerate crinoid has a quadrangular stem with pentagonal axial canal and 4 basals with sutures.

Description.- The radials are usually in the lateral interray with some interprimibrachs and small plates covering the radial sutures. The interbrachial areas are depressed and contain numerous small plates below adjacent rays. The arms are 2 to a ray with brachial half rays. Arms are uniserial to cuneate uniserial.

Discussion.- The information used is from S.A. Miller (1881, p.71), Brower (1974) and Ramsbottom (1961). There are 4 known species in the genus *Xenocrinus*. Two of the species *X. multiramus* Ramsbottom 1961 and *X. breviformis* Brower 1974 are from strata in Scotland. The above species have 4 arms per ray. It has been noted that the American species *X. penicillus* S.A. Miller 1881 and *X. baeri* (Meek 1972) have proximal interprimibrachs. These are from the Richmond Series of Ohio. *Xenocrinus* comes from xenos meaning strange or new and krinon meaning lily.

XENOCRINUS PENICILLUS S. A. MILLER 1881

Diagnosis.- *Xenocrinus* with 5 radials, 10 arms with cuneate uniserial brachials and numerous interradial plates.

Description.- See Table 3 Characteristics Species of *Xenocrinus*.

Discussion.-Several specimens of *Xenocrinus* sp. were studied. There were 44 specimens many are contained in slabs OSU 39219 & 39220, but only 3 of the well preserved specimens were studied in detail (OSU 39216 - 18, Fig. 13, 14). The longest attached stem was 6 cm in length. The largest calyx was 5 cm. All specimens were well preserved although the CD interray was not visible in any of them. Without an understanding of plates, the posterior

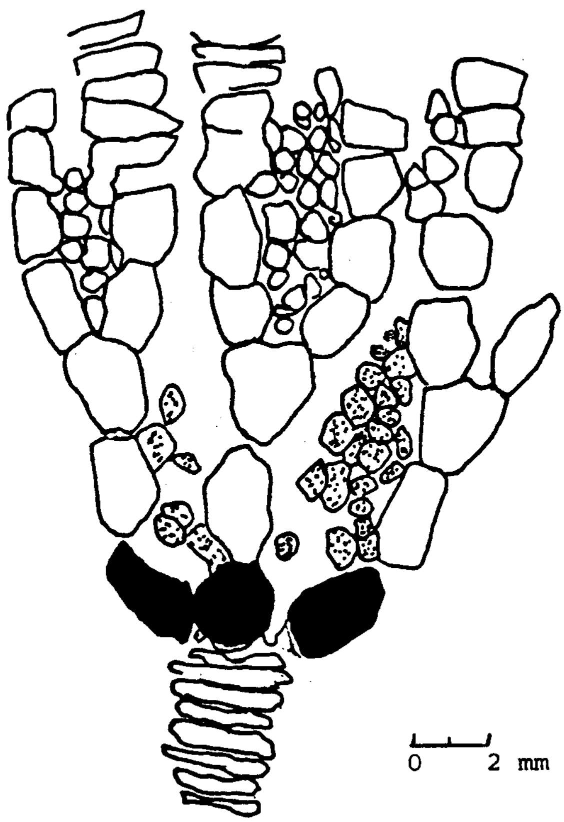


Figure 13

CAMERA LUCIDA DRAWING OF Xenocrinus penicillus S. A. MILLER
BLACK PLATES REPRESENT RADIALS, STIPPLED ARE INTERRADIALS.
OSU 39218

Figure 14

Crinoid plates 14.1 - 14.4

Xenocrinus penicillus S.A. Miller 1881

1-Lateral view of cup and arms, OSU 39216, 1.5X;

2-Enlargement of cup and lower arms, OSU 39216, 4.2X;

3-Lateral view of cup and arms, OSU 39218, 1.5X;

4-Enlargement of cup, OSU 39218, 3.1X. Specimens coated with ammonium chloride.


1


2


3


4

Figure 14 continued

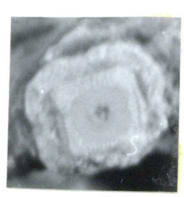
Crinoid plates 14.5 - 14.8

Xenocrinus penicillus S.A. Miller 1881

5-Lateral view of cup and arms, OSU 39217, 1.7X; 6-Enlargement of cup and lower arms, OSU 39217, 3.1X; 7-Quadrangular columnal, OSU 39217; 8-*Cincinnaticrinus* sp. columnals. Specimens coated with ammonium chloride.

5

6



7

8

identification is difficult. Specimen OSU 39218 in Fig. 14 had several extra plates beneath the radials and is viewed as an aberrant form.

XENOCRINUS BAERI (Meek 1872)

(Glyptocrinus baeri Meek 1872)

Diagnosis.- *Xenocrinus* with 10 arms with cuneate brachials, interradial pieces, and axillary spaces not excavated with projecting points.

Description.- See Table 3 Characteristics Species of *Xenocrinus*.

Table 3 Characteristics Species of Xenocrinus

	X. penicillus S.A. Miller 1881	*X. baeri* (Meek 1872)
Body:	elongate	wide calyx, medium size, globose, obconoidial(?)
Basals:	4, 2*HT=W, 2 hexagonal, 2 pentagonal, granuluos, sutures B,E,C,D rays	short, pentagonal
Primary Radials:	3, 2*W=L, convex, radial circlet join lateral	moderate size, heptagonal,

	interray	pentagonal
Secondary:	4,5,6,+	------------
Interradials:	constricted free into free arms, 25(?)	large number, small size, depressed, unequal, 6+ axillary areas, projecting points
Arms:	bifurcated, cuneate, uniserial brachials, 10, pinnulea quiet in contact	bifurcated, 10, long, simple, tapering, cuneate uniserial brachials, pinnulae long
Column:	quadrangular, round down stem, perforated orifice, 1/2 interarea = outerarea, pentagonal axial canal	quadrangular, moderate thickness, rounded sub-pentagonal,

		alternating thick and thin
Interradial Areas:	depressed, 75(?), numerous small plates	-------------
Location:	Warren County, Ohio; Hudson River Group, New York	Cincinnati, Ohio; Richmond, Indiana
Collector of Holotype:	D.T. Dycle of Lebonon, Ohio	Dr.O.P. Baer of Richmond, Indiana

DEPOSITIONAL INTERPRETATION

A rapid influx of sediment is suggested for the preservation of these crinoids. The crinoids were mostly all articulated with occasional attached stem segments up to 6 cm. Broken bryozoan fragments were observed within the arms and pinnules of several specimens.

Dissarticulation of crinoids has been described by Meyer (1971) and Liddell (1975). The pinnules and distal arm segments of killed crinoids disarticulate within 6 days if left exposed on the sea floor. Consequently, rapid burial is necessary for complete preservation of crinoid arms. Rapid burial must have occurred for the excellent preservation of the X. penicillus specimens under study.

The rapid burial of these crinoids is also supported by the lithologic and sedimentary characteristics of the accompanying stratigraphic sequence. The lenticular, irregular beds with gradational tops and scour features and sharp limestone contacts at the base all support a sedimentary regime of rapidly changing depositional energy. These conditions would occur during storm deposition, which would represent a rapid influx and deposition of sediment. The vugs found in thin section studies may represent air pockets from rapid deposition, as suggested by Kreisa (1981). The evidence of megaripples represents a high level of energy. Cross-bedding requires a bottom current. Stratigraphic, lithologic and paleontologic evidence for the *Xenocrinus* bed is consistant with the storm deposition hypothesis suggested by Kreisa, (1981).

CONCLUSIONS

This study has uncovered an occurrence of of *Xenocrinus penicillus* S.A. Miller 1881 with excellent preservation in strata representing storm deposits. The lithologic record contains evidence of rapid burial of these crinoids. In order for these specimens to be preserved, they must have been buried alive. The associated fauna was also identified. Although stratigraphy is difficult to determine, the rocks are considered to be part of the Bull Fork Formation. Field and laboratory descriptions of rock samples were studied for type and depositional environment.

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